Seabird abundance, distribution and breeding patterns in relation to the Leeuwin Current

R D Wooller, J N Dunlop, N I Klomp, C E Meathrel & B C Wienecke

Biological Sciences, Murdoch University, WA 6150, Australia

Abstract

Lack of upwelling, and low marine productivity, results in seabirds being much less abundant off Western Australia than along the coasts of western South America and south-west Africa. The breeding and non-breeding distributions of seabirds appear to be influenced by the presence of the Leeuwin Current, as do the timing and success of their breeding activity. For instance, in a year of strong Leeuwin Current flow, Little Penguins near Perth carried less food, were in poorer condition and laid eggs much later than in a year of weaker flow.

Abundance

On the western coasts of southern continents, regions of coastal upwelling often support rich, but locally restricted, seabird assemblages. The diversity of species in these communities is often similar but their abundances may differ greatly. Off Peru, about four million Peruvian Boobies *Sula variegata* breed, together with three million Guanay Cormorants *Phalacrocorax bougainvillii* and one million Peruvian Pelicans *Pelecanus thagus* (Duffy *et al.* 1984). The total numbers of seabirds off Peru are thought to have varied between four million and 20-30 million over the last century (Duffy & Siegfried 1987). Off the south-western coast of Africa the most abundant breeding seabirds are the Cape Cormorant *Phalacrocorax capensis* (280,000), the African Penguin *Spheniscus demersus* (170,000) and the Cape Gannet *Sula capensis* (80,000 birds).

Off the western coastline of Australia, upwelling is much less pronounced than along the coasts of western South America or south-west Africa (Pearce 1991), and populations of seabirds are much smaller (Serventy *et al.* 1971). Indeed, seabird densities off Western Australia were never large enough to accumulate massive guano deposits like those harvested off south-western Africa, Chile and Peru.

In most years, the Benguela and Humboldt Current systems off the western coasts of southern Africa and South America, and the associated upwellings which bring nutrients into the euphotic zone, result in large schools of pilchards, sardines, anchovies and sprats, which provide food for seabirds. It has long been known that seabird populations in the Peruvian and Ecuadorian coastal areas periodically experience major natural disasters due to malnutrition. A warm southward countercurrent usually only displaces the cold, north-flowing water between December - January and March - April, but occasionally strengthens and persists for a year or more, thereby reducing fish stocks (Schreiber & Schreiber 1984).

It is unclear how far the Leeuwin Current affects the abundances of seabirds off south-western Australia but the current has been linked to the changing distributions of seabird species in this region and to their patterns of breeding (Dunlop & Wooller 1990).

Non-breeding distributions

Pelagic seabird species from the Pacific Ocean recently recorded from the waters off Western Australia have been attributed to a marine continuity between the Leeuwin Current and the tropical, western Pacific Ocean (Dunlop *et al.* 1988a). These species include Tahiti Petrels *Pterodroma rostrata*, Bulwer's Petrel *Bulweria bulwerii*, Streaked Shearwaters *Calonectris leucomelas*, Hutton's Shearwaters *Puffinus huttoni*, Fluttering Shearwaters *P. gavia* and Matsudaira's Storm-petrels *Oceanodroma matsudairae* (Dunlop *et al.* 1988a, 1988b).

Breeding distributions

Along the western coast of Australia, some tropical seabirds breed much further southward than in eastern Australia, or even elsewhere in the world (Serventy *et al.* 1971). Common Noddies *Anous stolidus*, Lesser Noddies *A. tenuirostris* and Sooty Terns *Sterna fuscata* all have large breeding populations on the Houtman Abrolhos, well beyond their normal latitudinal limits

(Harrison 1983). Roseate Terns *Sterna dougallii* breed in Warnbro Sound and Bridled Terns *S. anaethetus* off Cape Leeuwin, both reaching the southernmost limits of their worldwide breeding ranges off the Western Australian coast.

Some marked extensions of breeding range have also been recorded relatively recently. After colonising Lancelin Island, probably from Abrolhos populations, the Roseate Tern started breeding in the Fremantle area about 1982 (Dunlop & Wooller 1986). Bridled Terns occurred no further south than the Abrolhos in 1839-1843, reached the Safety Bay islands by 1920, bred on Hamelin Island by 1955 and off Cape Leeuwin by 1957 (Serventy *et al.* 1971). On Penguin Island, in Shoalwater Bay, no Bridled Terns bred in 1940-42 but a substantial, and growing, breeding population had become established by the early 1980s (Dunlop *et al.* 1988c).

The Red-tailed Tropicbird *Phaethon rubricauda* has bred intermittently on the Houtman Abrolhos and from 1957 to 1959 on Rottnest Island (Storr 1964, Serventy *et al.* 1971), although the nearest large, stable breeding population of this species is on Christmas Island, in the eastern Indian Ocean (Harrison 1983). More recently, a small population of Red-tailed Tropicbirds have bred off Cape Naturaliste since 1966 (Serventy *et al.* 1971). The distributions of all these essentially tropical species appear to reflect the influence of the Leeuwin Current.

Seabird assemblages off southwestern Australia are often paradoxical, for instance near Fremantle, where tropical Bridled and Roseate Terns breed beside cool-water Little Penguins *Eudyptula minor*. On the Abrolhos, tropical Sooty Terns, Common Noddies and Lesser Noddies breed on the same islands as cool-water species such as Little Shearwaters *Puffinus assimilis*, White-faced Storm-petrels *Pelagodroma marina* and Pacific Gulls *Larus pacificus*. Off the south-west corner of Australia, Bridled Terns and Red-tailed Tropicbirds nest alongside species from cooler southern waters, such as the Fleshy-footed Shearwater *Puffinus carneipes*. Such paradoxes may be accounted for by the southward extension of tropical seabirds associated with the Leeuwin Current.

Breeding seasons

In south-eastern and southern Australia, seabirds typically breed in spring/summer, whereas in tropical northwestern and northern Australia most breed between March and June. However, on the mid-western and southwestern coasts of Australia, several seabird species breed both in autumn (March-June) and in spring (August-November), some breeding continuously from autumn to spring. Double-breeding or protracted breeding are seen in Crested Terns *Sterna bergii*, Bridled Terns, Roseate Terns, Pied Cormorants *Phalacrocorax varius*, Silver Gulls *Larus novaehollandiae* and Little Penguins (Dunlop & Wooller 1986).

Roseate Terns breed on islands from the Houtman Abrolhos to the Fremantle area in either autumn or spring, the seasonally distinct breeding groups being interspersed throughout these islands. On the Abrolhos, and several other islands, both autumn-breeding and spring-breeding colonies occur on the same island. Of the two recently established colonies, Roseate Terns breed in spring on Lancelin Island but in autumn in Shoalwater Bay (Dunlop & Wooller 1990). Most Crested Terns in southwestern Australia breed from August to December, but autumn-breeding colonies are known from the Houtman Abrolhos, the Fremantle area and east of Hopetoun. On Rottnest Island, autumn breeding did not appear to start until about 1977-1978, presumably as a result of an invasion of autumn-breeders from colonies on the Abrolhos or off the Pilbara coast (Dunlop & Wooller 1990). Detailed observations of individually marked Crested Terns in the Fremantle area have shown that individuals have a broadly circannual reproductive cycle and comprise two groups which are reproductively distinct, although some young born in spring have joined the autumn-breeding group (Dunlop 1985, Dunlop & Wooller 1990).

In the Silver Gull and the Little Penguin, breeding is greatly protracted and egg-laying shows two or more peaks. Both species are potentially double-brooded and readily replace lost clutches (Nicholls 1974, Wooller & Dunlop 1979, Dunlop *et al.* 1988b). Thus, protracted breeding results from sequential, successful, and unsuccessful, breeding attempts by the members of a single population, rather than by separate populations, as seen among terns.

Breeding success

The timing, strength and characteristics of the Leeuwin Current vary seasonally and from year to year. This variability appears to affect the reproductive performance of some seabirds, such as Little Penguins. Since 1986, most of the five hundred Little Penguins breeding on Penguin Island, near Rockingham, have been individually marked, measured and their reproductive success monitored in 55 nest-boxes and a similar number of natural nest-sites in bushes. The stomach contents of penguins coming ashore at dusk in 1986 and 1989 were also analysed (Klomp & Wooller 1988, Wienecke 1989).

In 1989, the mean body weights of male and female Little Penguins were significantly less than during 1986 (Table 1; $t = 13.77$ for males and $t = 7.90$ for females, both $p < 0.01$). These samples did not include moulting penguins but even non-moulting penguins vary seasonally in weight. Therefore, a condition index was calculated (body weight (g) ÷ (head length (mm) + beak depth (mm))) to compare condition independently of size. In 1989, both males and females had significantly lower condition indices than during 1986 (Table 1).

Table 1

The weights and condition of Little Penguins on Penguin Island, Western Australia, and their reproductive performance in 1986 and 1989. Sample sizes are shown in parentheses.

	1986	1989
Leeuwin Current	weaker	stronger
Sea surface temperature	cooler	warmer
Mean (±S.E.) body mass (g)		
Males	1570 ± 19 (152)	1432 ± 16 (145)
Females	1363 ± 13 (143)	1181 ± 13 (132)
Mean (± S.E.) condition index (g)		
Males	125 ± 12 (208)	117 ± 12 (200)
Females	118 ± 10 (182)	106 ± 10 (159)
Mean clutch size	1.9	1.9
Mean (±S.E.) egg weight (g)	53.8 ±0.7	53.8 ±0.2
Mean (±S.E.) egg length (mm)	56.2± 0.5	56.6± 0.3
Mean (±S.E.) egg width (mm)	42.6 ± 0.3	42.3 ±0.3
Percentage eggs hatched	64% (198)	65% (120)
Mean young per pair	0.6 (104)	0.7 (63)

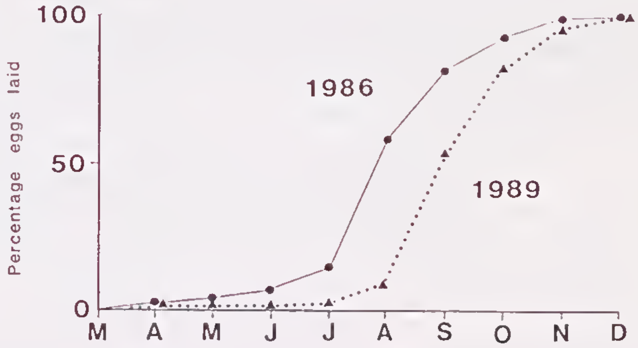

Figure 1 The cumulative monthly percentage of eggs laid by Little Penguins monitored on Penguin Island, Western Australia, during 1986 and 1989.

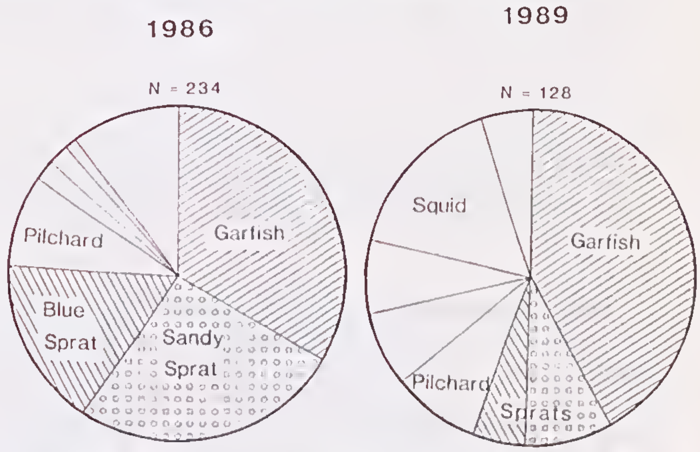

Figure 2 The composition of food samples obtained from Little Penguins ashore on Penguin Island, Western Australia, during 1986 and 1989.

The first penguin eggs were laid in April in both years and laying continued until December, typical of other years monitored. However, the main laying period was 1-2 months later in 1989 than 1986 (Figure 1). In addition, a lower proportion of birds bred in 1989 than in 1986, although clutch size, egg dimensions, hatching success and overall reproductive output were almost identical in both years (Table 1).

Of the 128 penguins sampled in 1989, 15.6% carried no food, significantly more than the 6.3% of 234 penguins sampled in 1986 ($X_1^2 = 72.1$, $p<0.001$). The samples from penguins with food in 1989 (12.5 ± 2.1 g) were much smaller than in 1986 (57.2 ± 10.3 g). However, the prey taken, mostly small, schooling fish, were very similar in both years (Figure 2).

Sea surface temperature at the edge of the continental shelf, near Perth, varied seasonally in a similar manner in both 1986 and 1989, but was up to 2°C warmer in 1989 (Figure 3). Temperatures closer inshore, where penguins feed, paralleled those further offshore, although they were more variable, with seasonal ranges of about 8°C inshore and 5°C offshore. The mean annual sea level at Fremantle, an indicator of the presence and strength of the Leeuwin Current (Pearce & Phillips 1988), was high in 1989, following a similarly high level in 1988. In contrast, 1986 and 1987 had low mean annual sea levels at Fremantle, presumably reflecting a much weaker Leeuwin Current, and cooler surface waters, in those years.

Food samples were not taken from Little Penguins during 1987 and 1988. However, the condition of the penguins was relatively good during 1987 but poorer in 1988. In 1989, the later laying period, poorer condition and lower proportion of birds breeding may have resulted from a warmer sea surface temperature adversely affecting the Little Penguin, which is essentially a cool-water species. This effect is, presumably, mediated through a lower abundance or availability of the schooling fish which form the diet of these penguins. Commercial catches of baitfish were, indeed, lower in 1989 than in 1986 (R. Lenanton, pers. comm.) but, in the absence of detailed information on fish stocks and distribution, it is only possible to infer the links between oceanographic events and seabird reproductive success at present.

Figure 3 Mean monthly sea surface temperatures (°C) off Rottnest Island, Western Australia, during 1986 and 1989. Data kindly provided by A.F. Pearce.

The invariability in the reproductive effort and success of those penguins which did breed may represent the minimal viable effort in accord with genetic fitness. The non-breeding individuals appear to defer breeding until later in the season, or until a later year, rather than attempt to breed sub-optimally. This strategy may have evolved under the variable oceanographic, and probably trophic, conditions produced by the Leeuwin Current. Interestingly, the Bridled Tern, a tropical species, appears to show a converse effect, arriving and laying earlier in years of stronger current flow and warmer sea surface temperatures (Dunlop & Jenkins, unpubl. obs.).

Conclusions

Variation in the strength of the Leeuwin Current appears to influence the reproduction and mortality of seabirds off Western Australia less dramatically than variation in the El Niño -Southern Oscillation can affect seabirds in the eastern and central Pacific. However, the presence of more tropical, and fewer cool-water, seabird species breeding off southwestern Australia seems clearly linked to this warm water current. The timing and duration of breeding seasons in the region also appear to reflect the seasonal effects of the Leeuwin Current, although much remains to be learned about the mechanisms underlying these relationships.

References

Duffy D C & Siegfried W R 1987 Historical variations in food consumption by breeding seabirds of the Humboldt and Benguela upwelling regions. In: Seabirds: feeding ecology and role in marine ecosystems (ed J P Croxall) Cambridge University Press, Cambridge. 327-346.

Duffy D C, Hays C & Plenge M A 1984 The conservation status of Peruvian seabirds. In: Status and conservation of the world's seabirds (eds J P Croxall, P G H Evans & R W Schreiber) ICBP Technical Publication No 2, Cambridge. 245-259.

Dunlop J N 1985 Reproductive periodicity in a population of Crested Terns *Sterna bergii* Lichtenstein in southwestern Australia. Aust Wildl Res 12:95-102.

Dunlop J N & Wooller R D 1986 Range extensions and the breeding seasons of seabirds in southwestern Australia. Rec West Aust Mus 12:389-394.

Dunlop J N & Wooller R D 1990 The breeding seabirds of southwestern Australia: trends in species, populations and colonies. Corella 14:107-112.

Dunlop J N, Cheshire N G & Wooller R D 1988a Observations on the marine distribution of tropicbirds, sooty and bridled terns, and gadfly petrels from the eastern Indian Ocean. Rec West Aust Mus 14:237-247.

Dunlop J N, Klomp N I & Wooller R D 1988b Penguin Island,Western Australia. Corella 12:93-98.

Dunlop J N, Wooller R D & Cheshire N G 1988c Distribution and abundance of marine birds in the eastern Indian Ocean. Aust J Mar Freshw Res 39:661-669.

Harrison P 1983 Seabirds: An identification guide. Croom-Helm, Beckenham.

Klomp NI & Wooller R D 1988 Diet of Little Penguins *Eudyptula minor* from Penguin Island, Western Australia. Aust J Mar Freshw Res 39:633-639.

Nicholls C A 1974 Double-brooding in a Western Australian population of the silver gull *Larus novaehollandiae* Stephens. Aust J Zool 22:63-70.

Pearce A F 1991 Eastern boundary currents of the southern hemisphere. In: The Leeuwin Current: an influence on the coastal climate and marine life of Western Australia. (eds. AF Pearce and DI Walker). J Roy Soc WA 74:35-46.

Pearce A F & Phillips B F 1988 ENSO events, the Leeuwin Current, and larval recruitment of the western rock lobster. J Cons Int Explor Mer 45:13-21.

Schreiber R W & Schreiber E A 1984 Central Pacific seabirds and the El Niño Southern Oscillation: 1982 to 1983 perspective. Science 225:713-716

Serventy D L, Serventy V & Warham J 1971 The handbook of Australian seabirds. AH & A W Reed, Sydney.

Storr G M 1964 The avifauna of Rottnest Island, Western Australia. I. Marine birds. Emu 64:48-60.

Wienecke B C 1989 The breeding patterns of Little Penguins on Penguin Island, Western Australia, in relation to dietary and oceanographic factors. Unpubl. B.Sc. Hons. Thesis, Murdoch University.

Wooller R D & Dunlop J N 1979 Multiple laying by the Silver Gull *Larus novaehollandiae* Stephens, on Carnac Island, Western Australia. Aust Wildl Res 6:325-355.